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How versus how often

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SUMMARY

Introduction (Chapter 1)

Societal debates about the riskiness and acceptability of controversial technologies have led scientists to propose and apply quantitative definitions of risk. In parallel to this, psychological research has focused on identifying the factors underlying risk judgments and risky decisions. One such factor is the (subjective) probability of a future loss or accident. The present monograph reports on a series of studies about the cognitive mechanisms underlying accident probability assessment.

For complex and realistic risky activities, accident probability judgments may be based on two fundamentally different types of information: frequency and scenario information. **Frequency information** refers to the outcomes of similar situations or activities in the past ("how often did accidents happen?"). **Scenario information** describes the way(s) in which a future accident may occur ("how might an accident happen?"). The aim of the present research was to study the role and relative importance of these types of information for risk judgment and risky decision making. Two main hypotheses were tested. The first is that, in general, people are sensitive to both frequency and scenario information; the second is that the relative importance attached to these types of risk information may vary, dependent on the nature and the quality of the information itself, the type of risky activity under consideration, and individual factors. In Chapter 1 these topics are introduced and the remainder of the book is outlined.

Psychological research on risk judgment (Chapter 2)

In a review of psychological studies on risk judgment and risky decision making, four research traditions are distinguished. In the **experimental tradition** well-defined lotteries have been used to study subjects' risk judgments and/or risky decisions. Using lotteries allows investigators to precisely manipulate and control relevant variables, e.g., outcome values and probabilities. This line of research has yielded a variety of - increasingly complex - risk measures, formulated in terms of elementary lottery components, outcome distribution characteristics, or axiomatically derived generic models. The external validity, however, of conclusions based on lottery studies is disputed.

Investigators in the **psychometric tradition** have asked subjects to rate or rank brief descriptions of realistic risky activities with regard to several evaluation criteria. Multidimensional scaling techniques were used to identify the cognitive dimensions underlying riskiness and acceptability judgments. 'Riskiness' was found to increase when potential losses are more serious and when the activity at hand is perceived as being less voluntary, less controllable, and less familiar. Risk acceptance appears to depend also on the benefits that may be gained. Due to the correlational nature of this type of study, the interpretation of results in terms of underlying causal mechanisms poses serious difficulties.

In the **personalistic tradition** interindividual differences in risk-taking tendency have been studied. Demographic variables (e.g., age, gender), personality traits (e.g., achievement motivation, locus of control), and variables which are both person- and activity-specific (e.g., experience, expertise) have all been shown to be related to people's risk-taking tendency. However, the transsituational generality of the obtained results tends to be low.

Social-psychological studies have focused on the effects of group processes on risky decisions. It was found that group discussions tend to magnify the initial inclinations of group members: there could be risky or cautious shifts of opinion. The precise mechanisms underlying this phenomenon are not well understood.

Studies in which the **relative importance** of the different factors or dimensions underlying perceived risk was compared indicate that 'probability of a loss or accident' is one of the more important constituents of perceived risk. However, the relative importance of this factor was found to depend on the specific value of the factor itself and on those of other relevant variables. This implies that general conclusions about the relative importance of the factors underlying perceived risk are not possible.

Probability theories and human probability assessment (Chapter 3)

Mathematical probability theory is a strictly formal theory; it specifies conditions that probability statements have to satisfy, but it does not specify how probabilities are related to real-world events. There are three dominant positions in a philosophical debate on the interpretation or meaning of probability statements. In the '**frequentistic**' school of thought, the probability of an event is defined as the limit of the relative frequency of this event in an infinite sequence of similar observations. According to the '**subjective**' interpretation, probabilities constitute a way in which people may express uncertainty; a singular probability statement expresses a personal opinion, the validity of which cannot be determined. In the '**logical**' school of thought, probabilities are comprehended as an extension of formal logic, describing a "degree of implication" between sets of formal propositions.

Whether people actually adhere to the rules prescribed by normative probability theory was one of the key questions in earlier psychological studies on **human probability assessment**. People appear to obey the normative rules in many instances, but under some circumstances large and systematic violations (or 'biases') occur. Later and more descriptive studies revealed that people solve probability assessment tasks by applying a limited number of relatively simple rules (so-called 'heuristics'). So far, this has yielded satisfactory answers to the question why people violate normative probability rules. However, as yet this approach has not resulted in a general descriptive theory of human probability judgment. What is lacking is a theoretical framework enabling one to predict which heuristic will be applied under what conditions.

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Frequency information and scenario information (Chapter 4)

Based on a review of the relevant literature, three **general strategies** for probability assessment are distinguished. Accident probability judgments may be based on: (a) relative frequency information, which is information about the outcomes of similar situations in the past; (b) cognitive scenario information, which is information about the way(s) in which a future accident may occur; and (c) logical deduction from knowledge about the outcome-generating process, given that the latter is relatively simple and completely understood. Since this is usually not the case for realistic risky activities, accident probability judgments concerning such activities will generally be frequency-based and/or scenario-based.

Frequency-based probability judgment requires two steps. First, the past frequency of the target event (e.g., an accident) has to be assessed. Information about past event frequencies may originate from several sources, e.g., personal experiences, accounts of specific incidents by others, or externally supplied statistical risk information. Subsequently, a simple rule is used to convert the available frequency information into a probability assessment: an event's probability of occurrence is judged to be higher if its past (relative) frequency of occurrence is higher. The relevance of frequency information for assessing future accident probabilities should depend on the normative quality of the available information. Three different quality aspects are indicated: credibility, statistical reliability, and substantive validity.

Scenario-based probability judgment also involves two stages. First, available knowledge about the activity in question is used to mentally construct relevant scenarios, i.e., coherent sequences of events resulting in the occurrence of the target event. The cognitive availability (or 'ease of mental construction') of accident scenarios then serves as a cue for the likelihood of future accidents: the accident probability is judged to be higher if it is more easy to imagine more different accident scenarios. The quality or plausibility of the available scenarios should also play a role. It is hypothesized that available scenarios will affect probability judgments more strongly when they are more internally consistent, complete, parsimonious, and concrete.

The **relative importance** of different types of available risk information may not only depend on the nature and the quality of the information itself. It may also depend on activity-specific and individual factors. Two such factors are indicated: the degree to which the activity at hand is perceived as personally controllable and the extent to which people have prior personal experience with the activity. It is hypothesized that scenario information will be more relevant if the risky activity at hand is personally controllable, whereas frequency information will be more influential if the activity is uncontrollable. Prior personal experience with a particular risky activity is expected to generally decrease people's sensitivity to (any type of) available risk information.

The above ideas are summarized in a **theoretical model** (Figure 4.1). The model presents the factors and processes involved in accident probability judgment and

risky decision making in a structured way. Specific hypotheses, to be tested in the empirical part of the study, are outlined. These refer to, successively: (a) the relation between accident probability assessments, risk judgments, and risk-taking decisions, (b) the nature and relative importance of frequency-based and scenario-based probability judgment, and (c) the role of 'personal control' and 'personal experience' in risk judgment and risky decision making.

Experiments (Chapters 5 through 8)

In *experiment 1* effects of frequency and scenario information variations on risk judgments and risky decisions concerning **small-scale**, personally controllable risky activities (e.g., car driving, mountain climbing) were studied. One hundred and twenty eight subjects read 16 descriptions of realistic decision problems, offering a choice between a risky and a safe alternative. Short paragraphs containing risk information could be inserted into each description. The inserted risk information was varied across subjects (either no information, only frequency information, only scenario information, or both). Within subjects, frequency information varied with regard to the height of the reported accident frequency and three different quality aspects: source credibility, statistical reliability, substantive validity; scenario information varied with regard to the number of suggested accident scenarios, their concreteness, and their controllability. For each risky activity subjects assessed the probability of an accident and indicated whether they would decide for or against the risky option.

Subjects appeared to base their accident probability judgments and, to a lesser degree, their risky decisions on both types of risk information, but scenario information was found to dominate frequency information; the added presence of scenario information clearly suppressed the effect of available frequency information. With regard to frequency-based risk judgment, it was found that reporting a higher past accident frequency resulted in higher accident probability judgments. The quality of the available frequency information, on the other hand, appeared to have been ignored by our subjects. With regard to scenario information, it was found that accident probability judgments were higher if more accident scenarios were made available and if the presented scenarios were more concrete. The degree of personal control implied by the suggested accident scenarios also influenced accident probability judgments; suggesting more personal control yielded lower risk judgments. Data from a post-experimental questionnaire revealed that greater 'personal control' and 'personal experience' go along with lower risk judgments and more risk-taking decisions.

In *experiment 2* a similar setup was used as in experiment 1. Ninety-six subjects read brief descriptions of risky choice problems into which short paragraphs of risk information were inserted. The main difference with experiment 1 was that all stimuli now referred to **large-scale**, personally uncontrollable risky activities (e.g., nuclear power generation, transport of hazardous chemicals). The inserted risk

information, now consisting of both frequency and scenario information, was varied with regard to: (a) the reported past accident frequency, (b) the quality of the frequency information, (c) the number of suggested accident scenarios, and (d) their concreteness. In addition, the suggested degree of personal control over the proposed risky activities was varied.

Several results from experiment 1 were replicated. Subjects gave higher risk judgments and decided less often in favor of the risky option when the reported past accident frequency was higher and when more accident scenarios were made available. Frequency information quality was again ignored by the subjects, whereas varying scenario quality did affect their responses. Subjects who had had personal experience with a particular risk again gave lower risk judgments and chose the risky option more often. Analysis of the combined data of experiments 1 and 2 revealed that frequency information plays a more prominent role when the risk at hand concerns a large-scale activity than when it concerns a small-scale one. Varying the suggested degree of personal control over the risky activities failed to affect the subjects' responses; this may have been due to difficulties in the operationalization chosen. Individual differences in 'locus of control' were found to be related to differences in risk judgments and people's sensitivity to risk information.

In *experiment 3* actual risk-taking behavior rather than imaginary situations and decisions were studied. One hundred and twenty eight subjects performed a **computerized laboratory task**. In each of 60 trials, subjects had to stop a fast moving symbol before it passed a target line. Success yielded a small gain; failure led them into a 'penalty task' in which they could incur a considerable loss. On each trial subjects chose among 10 risk levels (varying symbol speeds), low levels resulting in small but almost sure gains, whereas high levels yielded larger but less probable gains. Three penalty task characteristics were varied across groups of subjects: (a) the actual probability of loss (0.67 versus 0.33), (b) the external ('chance') or internal ('skill') determination of outcomes, and (c) the available risk information, which consisted of different combinations of frequency information and/or process information. The latter provided subjects with sufficient insight in the outcome-determining process to logically deduce the relevant probabilities.

Subjects took less risk (i.e., they failed fewer main task trials) when the actual loss probability in the penalty task was higher. Internal versus external determination of outcomes also significantly affected the subjects' risk-taking behavior; when the task appeared to be personally controllable, subjects took greater risk than when the task was not controllable, even though the actual loss probability was identical in both conditions. Subjects based their risk-taking behavior on the available process information, but they ignored the presented frequency information; neither the presence nor the content of frequency information affected the subjects' main task behavior. Interestingly, all experimental effects on the subjects' risk-taking tendency appeared to have been mediated through their **effort allocation** during task performance, rather than through the subjects' a priori (or 'risk-setting') decisions.

Experiment 4 was a field experiment. The effects of simultaneous variations in available risk information, degree of personal control, and amount of personal experience on **risk taking during car driving** were studied. Thirty-two novice drivers and 32 experienced drivers made a test drive along a rural road with many blind curves. Prior to the drive, all subjects had read a 2-page brochure which did or did not contain risk information about blind curves. The latter was systematically varied across subgroups of subjects (either no risk information, only frequency information, only scenario information, or both). Degree of task control was also varied: each subject made the same trip twice, once as the driver and once as a front-seat passenger. Passengers continuously indicated their 'preferred' speed choice. Both actual (driver) and preferred (passenger) speeds were registered at 20 curve locations.

Main findings were: presenting subjects with frequency and/or scenario information resulted in substantial curve speed reductions (about 6 km/h). The risk information effects were highly robust, i.e., they were similar in all 'personal control' and 'driving experience' subconditions. Degree of personal control over the task had a significant main effect on the subjects' speed choices, but the effect size was relatively small: actual (driver) speeds were less than 1 km/h higher than preferred (passenger) speeds. Amount of driving experience was positively related to risk taking, but - surprisingly - only for female drivers.

Discussion and conclusions (Chapter 9)

With one exception (viz. frequency information quality) all factors contained in our earlier model (Figure 4.1) were found to be related to people's tendency to take risk. However, since some of the relations among these factors were found to differ from prior expectations, a **revised theoretical model** is presented (Figure 9.1). Subsequently, main findings and conclusions with regard to each of the model components are discussed.

For a wide variety of risky activities and tasks it was found that the subjective **probability of a significant unwanted consequence** constitutes an important - though not the only - constituent of risk judgments and risk-taking behavior.

Our findings also demonstrate that people do not use some standardized mental algorithm for (accident) probability assessment. Instead, probability judgments result from several fundamentally **different cognitive strategies** that are applied in a flexible manner. Frequency information, scenario information, and, in some cases, process information may all serve as the basis for probability judgment.

Our expectations concerning **frequency-based probability judgment** were only partially supported; as expected, subjects gave higher accident probability judgments when the reported past accident frequency was higher. But contrary to expectations, the normative quality of available frequency information did not appear to play a significant role. People appear to utilize statistical risk information in a less 'critical' way than normative frequentistic probability theory would prescribe; possible explanations for this finding are suggested.

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Our expectations about the factors underlying **scenario-based probability judgment** were borne out. Subjects gave higher accident probability judgments when the availability of accident scenarios was higher and when the presented scenarios were qualitatively better. Scenario information also seems to serve as a cue for assessing the controllability of the activity at hand. It is argued that, as yet, insight into the mental processes involved in scenario construction and in the criteria upon which scenario quality evaluations are based is rudimentary. Promising paradigms for further research are indicated.

The present findings do not allow a general conclusion about the **relative importance** of frequency and scenario information for different types of activity and situation. Scenario information variations were found to have systematic and fairly robust effects on the subjects' responses. In contrast, frequency information effects were less stable and in some cases even inconsistent. People's sensitivity to statistical risk information seems to depend on a variety of factors, for instance, the informational conditions, the type of risk at hand, and individual characteristics (e.g., personality differences in 'locus of control'). However, the precise relationships between these factors and people's sensitivity to statistical risk information have not become clear.

Having prior **personal experience** with a particular risky activity was found to generally result in lower risk judgments and a greater tendency to take risk. This may be related to the fact that for the type of risks studied accidents are relatively scarce events and earlier experience is predominantly positive in nature.

Perceiving (more) **personal control** over a risky activity was found to generally lower risk judgments and to increase people's risk-taking tendency. The most plausible explanation for this effect is that people - usually correctly - assume that personal control may be used to steer an activity away from undesirable outcomes, thus lowering the probability of such outcomes. Contrary to expectations, personal control does not appear to be a crucial variable underlying the differences in people's sensitivity to frequency and scenario information.

Differences in personal control appear to affect the nature of risky decision making itself. The riskiness of uncontrollable activities depends on decisions which are made prior to the activity's undertaking (so-called '**risk-setting**' decisions); the outcomes of controllable activities, on the other hand, also depend on one's behavior when actually performing the task. For such tasks, people may react to increasing risk by changing their 'risk-setting' decisions, but also by improving their task performance, e.g., through **effort allocation**. The results of experiment 3 indicate that - at least in some instances - people prefer the second option. Implications of this notion are discussed. For instance, the above response pattern may reflect a general tendency to overestimate the degree to which activities are personally controllable and/or the extent to which the available (behavioral) resources are adequate. Such biases may result in excessive risk taking and, thus, contribute to accident occurrence. Secondly, in the case of personally uncontrollable activities risk may be expressed in terms of static probabilities; here, risky decision making largely amounts to gambling. In contrast, risk judgments concern-

ing controllable activities are necessarily conditional upon both the expected task demands and the expected personal capabilities, in terms of, e.g., skills, knowledge, and effort. For such tasks, a more dynamic ("stress-like") conceptualization of risk may be more appropriate: 'risk' reflects the extent to which the (expected) task demands exceed the available personal resources. Thirdly, it is argued that our own ideas, e.g., about the informational determinants and the stress-like nature of perceived risk, may be fruitfully combined with the risky-choice theory proposed by Lopes (1987) and with 'closed loop' driver behavior models to yield an adequate framework for analyzing decision making about and behavior in personally controllable risky activities.

In the **epilogue** it is argued that the present research differs in several respects from earlier studies on risk judgment and risky decision making. Methodologically, we have combined elements of the 'experimental' and the 'psychometric' research traditions (see Chapter 2). Theoretically, it has become apparent that risk judgment and risky decision making involve and, in fact, result from - sometimes extensive - cognitive information processing. Therefore, research into this area should be more cognitive-psychological in nature than it used to be.